PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : F16L 55/165	A1	(11) International Publication Number: WO 93/06410 (43) International Publication Date: 1 April 1993 (01.04.93)

(21) International Application Number: PCT/US92/07751

(22) International Filing Date: 11 September 1992 (11.09.92)

(30) Priority data:
759,419 13 September 1991 (13.09.91) US

(60) Parent Application or Grant
(63) Related by Continuation
US 759,419 (CIP)
Filed on 13 September 1991 (13.09.91)

(71) Applicant (*for all designated States except US*): COMPOSITE COMPONENTS, INC. [US/US]; 632 Wheeling Road, Wheeling, IL 60090 (US).

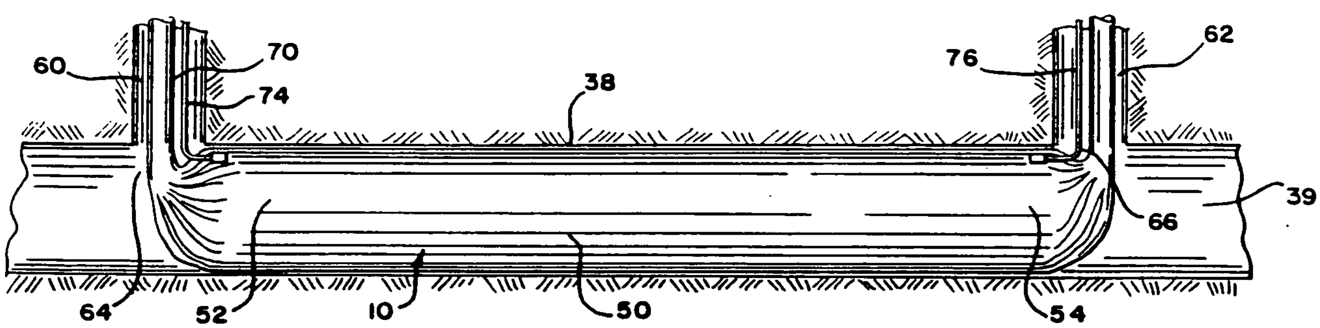
(72) Inventors; and
(75) Inventors/Applicants (*for US only*) : BLACKMORE, Richard, D. [US/US]; 914 Dell Road, Northbrook, IL 60062 (US). SLEEZER, Philip [US/US]; 16954 W. 144 Street, Lockport, IL 60441 (US). SCHMIDT, Alan [US/US]; 3830 W. Sawmill Lane, Morris, IL 60450 (US).

(74) Agents: STINE, Thomas, K. et al.; Wallenstein, Wagner & Hattis, Ltd., 311 S. Wacker Drive, 53rd Floor, Chicago, IL 60606-6604 (US).

(81) Designated States: AT, AU, BB, BG, BR, CA, CH, CS, DE, DK, ES, FI, GB, HU, JP, KP, KR, LK, LU, MG, MN, MW, NL, NO, PL, RO, RU, SD, SE, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, SE).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: METHOD OF FORMING AND REFORMING A PLASTIC COMPOSITE



(57) Abstract

A lining (10) and method for in situ rehabilitation of a pipe is disclosed. The lining comprises a tubular shaped resin impregnated composite (20) having a conductive layer surrounding an inflatable bladder (30). The method comprises the steps of positioning the lining (10) within a pipe section, inflating the bladder (30) until the lining is in contiguous contact with the interior of the pipe and inducing an electric current through the conductive layer (24) to resistively heat the lining and cure the impregnated resin. A method of reforming a composite part, such as a pipe lining, is also enclosed. The reforming method comprises heating a composite having a thermosetting resin which has been allowed to cure sufficiently so that the resin goes into an elastic state. Pressure is then applied to reform at least a portion of the composite part while the resin is in the elastic state.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	FI	Finland	MN	Mongolia
AU	Australia	FR	France	MR	Mauritania
BB	Barbados	GA	Gabon	MW	Malawi
BE	Belgium	GB	United Kingdom	NL	Netherlands
BF	Burkina Faso	GN	Guinea	NO	Norway
BG	Bulgaria	GR	Greece	NZ	New Zealand
BJ	Benin	HU	Hungary	PL	Poland
BR	Brazil	IE	Ireland	PT	Portugal
CA	Canada	IT	Italy	RO	Romania
CF	Central African Republic	JP	Japan	RU	Russian Federation
CG	Congo	KP	Democratic People's Republic of Korea	SD	Sudan
CH	Switzerland			SE	Sweden
CI	Côte d'Ivoire	KR	Republic of Korea	SK	Slovak Republic
CM	Cameroon	LI	Liechtenstein	SN	Senegal
CS	Czechoslovakia	LK	Sri Lanka	SU	Soviet Union
CZ	Czech Republic	LU	Luxembourg	TD	Chad
DE	Germany	MC	Monaco	TG	Togo
DK	Denmark	MG	Madagascar	UA	Ukraine
ES	Spain	MI	Mali	US	United States of America

METHOD OF FORMING AND REFORMING A PLASTIC COMPOSITE

DESCRIPTION

Technical Field

The present invention generally relates to a shaped fiber reinforced composite, and method of forming same, and, more particularly, to a pipe liner and a method for rehabilitating a damaged or deteriorated pipe. The present invention further relates to a method of reforming a cured composite, and, more particularly, to a method of reforming a distort d or improperly formed pipe lin r.

Background Prior Art

A shaped part, made from a fiber reinforced plastic c mposite is typically formed by impregnating th c mp site with a resin in a mold while ambient heat cures the resin. This has traditionally been done in an open mold, an extremely expensive device, which can take up to 24 hours to complete the cure process of the resin matrix composite. Hence, prior to the development of the present invention, a need existed for shortening resin cure process times by improving the expensive open molding process.

U.S. Patent No. 4,560,428 (Sherrick) discloses a system and method for producing a composite or laminate applicable for repairing damage to a structural component. An electrical resistance heating element in the form of a layer of graphite fibers is provided in contact with, or forming part of, a patch comprising a heat curable resinous material. A heat bondable adhesive film is positioned between the structural component and the patch. Electrical resistance is then used to cure the resin and bond the patch to the structural component.

Fiber reinforced plastic composites can also be used in rehabilitating damaged sewer pipe lines. The prior art contains many linings and methods for rehabilitating pipe lines. These range from excavating and replacing damaged sections of pipe to inserting smaller diameter pipes into the damaged sections. There are also several methods directed to providing various linings which may be inserted into the damaged pipes, some of which contain a resin which is subsequently cured to form a hardened shell lining the pipe.

A method disclosed in U.S. Patent No. 4,768,562 (Strand) comprises pulling an elastomeric tube through a damaged pipe. The elastomeric tube has a diameter substantially equal to the inner diameter of the pipe and is encompassed by an electrically conductive resinated fiber lattice that radially contracts when axially elongated. The lastomeric tube and resinated fib r lattice are axially tensioned, whereby the maximum

diameter of the liner is elastically reduced by the resultant elongation th reof. The resin is th n partially polymerized so that the liner is maintained in such condition. After being pulled through the pipe, an electric current is directed through the resinated fiber lattice, thus softening the resin by electrical resistance heating. The elastomeric tube, no longer restrained by the resinated fiber lattice, resiliently expands radially outwardly until it resumes its prior shape. The liner is further heated electronically so as to completely polymerize the resin, thereby bonding the liner to the inner wall of the damaged pipe. Thus, the elastomeric tube is used to position the resinated fiber lattice within the pipe and the polymerized resin is used to secure the elastomeric tube to the inner wall. Strand postulates using a metallic fiber lattice to conduct the electrical current through the lining. The fiber lattice only expands as far as the elastomeric tube. Thus, unwanted gaps between the pipe and the lining may exist in areas if the pipe does not have a constant diameter.

Certain lightweight materials, such as graphite or kevlar, known for their ability to greatly strengthen cured composites have not been used in pipe liners due to their expensive per pound cost.

Hence, prior to development of the present invention, a need existed for forming composites reinforced and strengthened with a lightweight material, such as graphite, and for curing these composites in less time and at less expense than in previous methods.

Resins, which are used as an element in the composite part, are typically classified as either thermoplastic or thermosetting. Thermoplastic resins soften when heated but harden again when they are cooled. Softening and rehardening does not significantly alter the properties of a thermoplastic resin. This allows a thermoplastic resin to be shaped and reshaped very asily. Unf rtunately, th rmoplastic resins ar n t as str ng as thermosetting resins and cann t withstand the same level of stress as a thermosetting resin.

Thermosetting resins undergo a chemical transformation called "curing." Curing is brought about by the action of heat or by the addition of chemicals. Before curing, thermoset resins may be in liquid or solid form but capable of being shaped under pressure and heat. After a thermosetting resin has been cured, it is typically extremely difficult to reshape. A thermosetting resin is characterized by a significantly cross-linked polymer network which hardens upon curing. The significant cross-linking in a cured thermosetting resin tends to give improved physical properties but does not easily permit remolding or reshaping of the resin after curing. Because cured thermosetting resins have many advantageous properties, they are used to make strong, lightweight composite parts. Synthetic thermosetting resins are preferably made in two-part form, wherein a resin is combined with a separate hardener or catalyst which helps cure the resin.

Resin impregnated pipe linings used for in situ rehabilitation of damaged pipes typically use thermosetting resins because of their preferred physical properties when in a cured state. However, if a pipe lining is not properly formed when it is initially allowed to cure, it will have to be removed and replaced. Removal and replacement of improperly formed pipe liners can be extremely costly. Accordingly, there exists a need for a cost effective method for fixing improperly formed pipe liners which include a thermosetting resin which has been allowed to cure.

Summary of the Invention

The broad aspects of the present invention involve a meth d of curing a preformed molded c mposite comprising an electrically conductive layer, such as woven graphite fiber. The method comprises the steps of impregnating the composite with a resin and compressing the composite in a mold while inducing an electric current through the conductive layer sufficient to raise the temperature of the conductive layer by electrical resistive heating to cure the resin. The electrically conductive layer is embedded within the composite, thus the composite is heated from within. In this manner, an exothermic reaction occurs in the resin more rapidly than a composite which is heated from its outside surface. In fact, the time required to cure the resin is about one-half the time required if the composite was heated from an external source.

Specific applications of the present invention are comprehended for curing preshaped fiber reinforced boat hulls, tennis rackets, golf club shafts, decks, and structural or exterior parts of automobiles, trucks, or recreational vehicles.

Another application of the broad aspects of the present invention is for providing a lining, and a method for in situ rehabilitating, a damaged or deteriorated pipe section.

According to the method for rehabilitating and lining a damaged or deteriorated pipe, a composite tube comprising a conductive layer, such as woven graphite fiber, is formed around a tubular shaped expandable bladder, such as polyurethane. Next, the lining is impregnated with a resin so that the conductive layer forms an internal heating element. The lining and the bladder are positioned along an interior section of a hollow pipe line having a substantially tubular shaped interior wall. The bladder is then inflated so that th lining is pressed against the interior wall. Finally, an el ctrical current is induced or p wered thr ugh the c nductive layer. The electrical current is sufficient

to resistively heat the conductive layer to cause the resin impregnated within the lining to cure. This cure molds the lining to the interior wall of the pipe line and to the bladder, thus forming a strong reinforced waterproof shell within the damaged pipe.

If woven graphite fiber is used as the conductive layer, it may be coated with other suitable materials to increase its ability to generate resistive heat. Also, in addition to assisting in the curing of the impregnated resin, woven graphite fiber provides other beneficial properties which enhance the life span of the composite. Graphite fiber exhibits strength exceeding that of high-strength steels. Under fatigue loading, graphite fiber has virtually unlimited life. Additionally, when added to a matrix material, graphite fiber reduces the coefficient of friction and increases wear resistance. Also, graphite fiber is inert to a wide variety of chemicals. Composites made with graphite fiber are approximately 40% lighter than aluminum, they are stiffer than titanium and can be designed to have a zero coefficient of thermal expansion. Additionally, graphite composites have excellent structural damping compared to metals.

Also, additional layers of fibers or fabrics may be added to the composite to further reinforce and strengthen the lining, creating a hybrid advanced composite preform.

In addition to forming a composite part or element, the present invention provides a method for reforming a distorted or improperly formed composite element. It is typically difficult to reform a composite element which includes a cured thermosetting resin. However, suitable selection of a thermosetting resin system which exhibits thermoplastic characteristics near or above the glass transition temperature of the system makes it possible to reform the comp site element after it has cured. An ep xy polymer having significant thermoplastic characteristics which permits realignment of the network of cr ss-links which occur during curing is preferred.

According to the method of reforming a distorted r impr perly formed cured composite elem nt, a composite element which has b en impregnated with a thermosetting resin which has been allowed to cure is heated sufficiently to cause the cured resin to reach a rubbery or elastic state. While the resin is in the elastic state, pressure is applied to reform the composite element.

According to a preferred aspect of the invention, the composite which has been impregnated with an epoxy resin system which has been allowed to cure is heated to near or above the glass transition temperature of the system. The composite is then cooled down from this temperature while maintaining pressure on the composite element as the resin rehardens or recures.

In another preferred aspect of the reforming method, the composite element includes a conductive element, preferably embedded within the composite element, such as a layer of graphite fiber, and the composite element is resistively heated by inducing or powering an electric current through the conductive element. In this manner, the glass transition temperature of the resin system is easily reached.

The reforming method can be directly utilized in reforming a distorted or improperly formed pipe lining used for in situ rehabilitation of pipes. A variety of reasons, such as failure to completely drain or remove excess water which has accumulated between the pipe lining and the pipe during initial formation, may cause the pipe lining to be improperly formed. An improperly formed pipe lining must be repaired or replaced in order to operate effectively.

According to the embodiment of the method for reforming a pipe lining, a portion of which is distorted or improperly formed, a pipe lining that includes a thermosetting resin system which has been allow d to cure is heat d sufficiently to cause the cured resin to achieve a rubbery or elastic state. Pressur is then applied to reform r reshape the improperly formed

portion of the pipe lining to its desired form while the resin is in the elastic state.

In a preferred embodiment of th method for reforming a pipe lining, th pipe lining includes a conductive element, preferably located within the pip lining such as a layer of graphite fiber. The pipe lining is then resistively heated by inducing an electric current through the conductive layer.

According to another preferred aspect for reforming a pipe lining, the pipe lining is impregnated with a thermosetting resin system which has a predetermined glass transition temperature and the resin is heated to near or above the glass transition temperature to achieve a rubbery or elastic state. The pipe lining is reformed by positioning an inflatable bladder inside the pipe lining and inflating the bladder. The inflated bladder engages the inner wall of the pipe lining and forces improperly formed portions of the pipe lining into their desired form. The bladder also maintains the desired shape of the properly formed portions of the pipe lining during the reforming operation. The bladder is kept inflated until the resin rehardens or recurs. The bladder may also be thermally bonded to the pipe lining and thus, become a part of the pipe lining.

Other advantages and aspects of the invention will become apparent upon making reference to the specification, claims and drawings to follow.

<u>Brief Description of Drawings</u>

Figur 1 discloses a perspective section taken through one embodiment of a pipe liner made in acc rdance with the present invention;

Figure 2 discloses a perspective section taken through another embodiment of a pipe liner made in accordance with the present invention;

Figure 3 discloses a perspective view of the partially formed pipe liner of **Figure 1**;

Figure 4 is a diagrammatic illustration of the pipe liner of **Figure 1** positioned inside a pipe section;

Figure 5 is a diagrammatic illustration of a pipe section being cleaned;

Figure 6 is a diagrammatic illustration of an inspection camera being pulled through the pipe section;

Figure 7 is a diagrammatic illustration of the pipe liner of **Figure 1** being positioned within a pipe section; and

Figure 8 is a diagrammatic illustration of the pipe liner of **Figure 1** inflated.

Figure 9 is a diagrammatic illustration of an improperly formed pipe lining during a reforming operation.

Figure 10 is a perspective cross-sectional view along the line 9-9 of the improperly formed pipe lining of **Figure 9** during the reforming operation.

Detailed Description

While this invention is susceptible of embodiment in many different forms, there is shown in the drawings and will herein be described in detail, preferred embodiments of the invention with the understanding that the present disclosure is to be considered as an exemplification of the principles of the invention and is not intended to limit the broad aspect of the invention to the embodiments illustrated.

A first embodiment of the present invention involves forming a lining for rehabilitating damaged or deteriorated pipe sections, and a method of use. As shown in **Figure 1**, a lining, generally designated 10, used for rehabilitating a damaged or deteriorated pipe (**Figure 4**) in situ comprises a woven graphite fiber reinforced composite 20 surrounding a bladder 30.

One pound of graphite can be formed into approximately two to three square yards of a woven fiber fabric while still retaining considerable strength. Using graphite in this form is cost effective, especially in view of the potentially enhanced life span of a product reinforced with graphite.

The composite 20 includes a first layer of spun bonded synthetic fabric 22, such as a polyesther or a nylon, a layer of woven graphite fiber 24, and a second layer of spun bonded synthetic fabric 26. The woven graphite fiber layer 24 separates and spaces apart the first spun bonded synthetic layer 22 and the second spun bonded synthetic layer 26. These layers 22,24,26 are ultimately subjected to a needle punch operation which mechanically binds and interlocks the layers 22,24,26 into a single composite fabric.

The bladder 30 is formed in a tubular shape having a hollow interior and opposing ends 32,34 spaced apart a distance approximately equal to a length of a section 38 of pipe 39 which is to be rehabilitated. The bladder 30 is preferably made out of a flexible material, such as polyurethane.

A rectangular portion of the composite 20, shown partially folded around the bladder 30 in **Figur 3**, having opposing sides 40,42 and opposing ends 44,46 is cut from the composite fabric. The ends 44,46 are spaced apart a distance approximately equal to the length of the section 38 of pipe which is to be rehabilitated. Th sides 40,42 are spaced apart a distance slightly farther than the circumference of the pipe line section 38.

The rectangular portion of composite 20 is formed into a tubular shaped section 50 surrounding the bladder 30 by connecting side 40 to side 42, as by seaming or stitching. The tubular shaped section 50 having ends 52,54 will thus have a circumference and diameter approximately equal to the circumference and diameter of the pipe line section 38.

When the composite 20 is formed into the tubular shaped section 50, the first spun bonded synthetic layer 22 becomes the outer layer of the tube. Similarly, the second spun bonded synthetic layer 26 becomes the inner layer of the tube, with the graphite fiber layer 24 being contiguously disposed between the outer and inner spun bonded synthetic layers.

To form the lining 10, the tubular section 50 surrounding the bladder 30 is first given a bath with a two part thermal setting resin system in a resin impregnator. The two part thermal resin system comprises an A-side resin combined with a B-side hardener. In order to prevent gaps forming between the lining 10 and the pipe line section 38, it is important to use a resin system which will not contract or shrink when cured, such as an epoxy resin system. Additionally, the resin system should be hydrophobic (i.e., it will set up in water), with low viscosity, chemically resistant and have a sufficient pot life. The pot life corresponds to the time it takes the resin system to begin to harden after it has been impregnated into the composit . The pot life should be long en ugh to allow the lining to be positioned inside a pip as explained below.

A two part thermos tting resin system having th properties mentioned is preferably made having approximately two parts of a blended diluent polyamide A-side and one part of a blended aliphatic polyamin B-side. The A-side is a blend of 75% Epotuf® epoxy resin 37-127 and 25% Epotuf® epoxy resin 37-137, which can be obtained through Reichhold Chemicals, Inc. located in Pensacola, Florida. The B-side is a blend of 33% Epotuf® epoxy hardener 37-360, 33% Epotuf® epoxy hardener 37-607, and 33% Epotuf® epoxy hardener 37-614, also available through Reichhold Chemicals, Inc.

Before placing the lining 10, access tunnels 60,62 must be created, if no existing tunnels such as those found in some sewer lines are present, at both ends 64,66 of the damaged pipe section 38. As shown in **Figure 5**, the damaged pipe section 38 is then cleaned, as by pressure flushing. Next, the pipe section 38 is inspected, and lateral pipe lines, if any exist, are located with remote control television cameras shown in **Figure 6**.

The resin impregnated lining 10 is then pulled through and positioned within the interior of the pipe line section 38. A closed cell foam plug 68, shown in **Figure 7**, is pulled in front of the lining 10 to further clean the pipe section 38 and to drive any water out of the pipe section.

Once through the pipe section 38, the closed cell foam plug 68 is inserted into the bladder 30 and the end 34 is connected by a hose 70 to an air compressor. The bladder 30 is inflated with compressed air, forcing the plug 68 back through the bladder 30 and causing the bladder 30 to expand radially. This drives out any water which has seeped in between the pipe section 38 and the lining 10 while the lining 10 was being positioned within the pipe section 38. The bladder 30 is allowed to expand until the composite 20 is pr ssed firmly against the inner wall of th pipe section 38 as sh wn in **Figure 8**. Sinc th comp site 20 is primarily spun b nded synth tic and woven graphite fib r, the c mposite 20 has the

ability to locally stretch or expand. This property is important because the diameter of the inner wall of a pip section may vary by as much as 10% along th length of th pipe section. Th ability of composit 20 to stretch will insure that there will be contiguous contact, without any gaps, between the lining 10 and the inner wall of the pipe section. Once the plug 68 is through the bladder 30, the end 32 of the bladder 30 is sealed closed. Alternatively, the bladder may b connected to the air compressor by suitable hoses at both ends.

While the composite 20 is confined between the inner wall of the pipe line section 38 and the inflated bladder 30, power lines 74,76 coupled to a conventional power source (not shown) capable of producing an electrical current are connected at the ends 52,54 to the woven graphite fiber layer 24 to create an electrical circuit. The power source induces an electrical current through the woven graphite fiber layer 24. The current is increased to a level where heat generated by electrical resistance in the woven graphite fiber layer 24 is sufficient to cure the resin impregnated in the composite 20.

The electrical current necessary to heat the composite to a sufficient temperature to cure the impregnated resin will depend on a variety of factors. For instance, the size of the composite (length, circumference, surface area), the ambient temperature of the composite and pipe section, and the type of resin being used, are all factors which will influence th amount of current needed. The weave of the graphite fiber can also affect the amount of current.

In laboratory testing, a piece of fabric, constructed from graphite fiber, three feet in length and one foot wide produced the following current and temperatur s when various voltages were applied to it:

Voltag (Volts)	Curr nt (Amps)	Temperature (°F)
5.00	9.50	86.20
7.50	14.00	103.80
10.00	18.00	126.60
12.50	21.00	150.50
15.00	29.00	186.50
17.50	35.00	218.50
20.00	41.00	253.00

The resin goes through several distinct phases when heated. Initially the resin will form a gel, it then enters a tack-free phase and finally goes into a hardened cured phase. To reach the tack-free phase, an exothermic reaction occurs and the resin will be sufficiently rigid and will no longer need to be heated to reach the hardened cured phase. Therefore, both the air compressor and the power source may be disconnected from the lining 10 at this time. After two hours, the resin will enter its final hardened cured phase.

The exothermic reaction occurs when the resin mass is heated to a specific temperature. At this point the resin begins to heat itself and does not require additional heating. It has been found that when the heating element is positioned internally, that is, within the resin impregnated composite, this specific temperature is reached more quickly and the resulting cure time is approximately one-half the cure time associated with externally heating the composite.

It is possible, depending on the approximate temperature achievable for a given set of conditions (e.g. length and surface area of lining, power source available), to formulate resins which have a suitable curing temperature.

During the curing process the composite 20 is bound on its outer surface to the inner wall of the pipe line section 38 and on its inner surface to the bladder 30 to form a hard strong graphite reinforce waterproof lining 10 within the pipe section 38. The resin used must n t shrink or contract during this process in ord r to avoid

gaps forming between the interior wall of the pipe section 38 and the lining 10.

Once the lining 10 is cured, th end 32 of the bladder 30 is reopened. Remote control television cameras are used to relocate any lateral pipes discovered when inspecting the pipe section 38. The lateral pipes are reopened utilizing conventional, remote control cutters.

In another embodiment shown in **Figure 2**, additional layers, such as an organic or synthetic fiber layer, may be sandwiched between the first spun bonded synthetic layer and the second spun bonded synthetic layer of the composite. The organic or synthetic fiber provides additional strength and reinforcement to the lining 10.

The lining 10 described may also be used to repair and reinforce other structures, such as sewer access tunnels.

Another embodiment of the broader aspects of the present invention involves a method of curing a shaped part made from a graphite fiber reinforced composite plastic, such as a boat hull. A composite comprising a layer of woven graphite fiber surrounded on both sides by several layers of fiberglass is preformed into the shape of a boat hull. The composite is then thoroughly impregnated with a resin. The resin impregnated composite is placed into an open or compression mold. The composite is electrically coupled to a power source at the lips of the mold to create an electrical circuit. While the composite is being laid up or compressed in the mold, the power source is operated to induce an electrical current through the woven graphite fiber layer. The current is increased until heat generated by electrical resistance in the woven graphite fiber layer cures the resin impregnated within the composite.

The mold which compresses and holds the composite during the curing process can be a polyester resin mold which costs far less than the thermal compression molds currently being used. Using this method, the boat hull can be cur d in approximately 2 hours as opposed to the

approximately 24 hours n eded with the open mold method of hand lay up.

A pr ferred method of reforming a distorted or improperly formed pipe lining 10' is shown in **Figur s 9** and **10**.

When rehabilitating a section 38' of a pipe 39' with a pipe lining 10', it is important to prevent gaps from forming between the pipe 39' and the lining 10'. However, a small percentage of pipe linings 10' are improperly formed and include portions 80 which are distorted and not in contiguous contact with the section 38' of pipe 39' being rehabilitated. This may be due to a variety of reasons. For example, water may seep through cracks in the pipe 39' while the pipe lining 10' is initially installed. This forces a portion 80 of the lining to separate from the pipe 39'. When the pipe lining 10' cures, the distorted portion 80 hardens in place.

Prior to the present invention, if a pipe lining 10' was unacceptable due to improperly formed portions 80, it was removed, if possible, and reinstalled. If it was not possible to remove the pipe lining 10, the entire section 38' of pipe 39' had to be excavated and replaced. Both these methods are expensive since they require a considerable amount of time and replacement of raw materials.

According to the preferred method for reforming a pipe lining 10', the pipe lining 10' includes a first layer of spun bonded synthetic fabric 22', a second layer of spun bonded synthetic fabric 26' and a layer of woven graphite fiber 24' between the layers of spun bonded synthetic fabric 22', 26'. The layers 22', 24', 26' being impregnated with a thermosetting resin system which has been allowed to cure. The lining 10' may also include a bladder 30 thermally bonded to the lining 10'.

Subsequent testing has shown that the thermosetting resin system is preferably a two-part system having an A-side of 75% Epotuf epoxy resin 37-127 and 25% Epotuf p xy resin 37-137, which can be obtained through

Reichhold Chemicals, Inc. located in Pensacola, Florida, and a B-side of Proprietary Blended Catalyst 607B which can be obtained from Henkel, Inc. located in Kankakee, Illinois. The A-side and B-side are combined in approximately equal measures.

To reform the pipe lining 10', an inflatable bladder 30' is positioned within the pipe lining 10' and is inflated until it engages the inner wall of the pipe lining 10'. The bladder is inflated by hoses 70' connected to an air compressor (not shown). Alternatively, if the old bladder is in adequate condition, it may be used to inflate the lining 10'. Power lines 74', 76' connected to a power source 77 such as a generator are secured to opposing ends of the pipe lining 10'. The power lines 74', 76' are connected to exposed portions of the graphite fiber layer 24' in the lining 10'. An electric current is induced through th layer of graphite fiber 24' in the lining 10' to resistively heat the lining 10' to near or above the glass transition temperature of the resin system. In the case of the preferred resin system described, the glass transition temperature is about 150°F.

The lining 10' is heated until the cured resin goes into a rubbery or elastic state. While in the elastic state, pressure from the inflated bladder 30' causes the improperly formed portions 80 to move radially outward and come into contact with the pipe 39'. The bladder is kept inflated as the reformed lining 10' rehardens or recures in its desired shape.

While the specific embodiments have been illustrated and described, numerous modifications come to mind without significantly departing from the spirit of the invention and the scope of protection is only limited by the scope of the accompanying Claims.

CLAIMS

1. A lining for in situ rehabilitation of a pipe comprising:

a tubular shaped resin impregnated composite having an interior surface and an exterior surface, said composite having a conductive layer; and

an inflatable tubular shaped bladder positioned within said composite contiguous to said interior surface of said composite.

2. The lining of Claim 1 wherein said composite further comprises a layer of vitreous fiber.

3. The lining of Claim 1 wherein said conductive layer comprises woven graphite fiber.

4. The lining of Claim 1 wherein said bladder is formed of polyurethane.

5. The lining of Claim 1 comprising a first polyester layer and a second polyester layer, and said conductive layer is disposed between said first polyester layer and said second polyester layer.

6. The lining of Claim 1 wherein said resin is an epoxy.

7. A lining for in situ rehabilitation of a pipe comprising:

a tubular shaped cured epoxy resin impregnated composite having an interior surface and an exterior surface, said composite including an outer layer of polyester, an inner layer of polyester, and a layer of woven graphite fiber contiguously disposed between said outer polyester layer and said inner polyester layer, said outer polyester layer defining said exterior surface and said inner polyester surface defining said interior surface; and

a tubular shaped polyurethane bladder positioned within said composite and thermally bonded to said interior surface of said composite.

8. The lining of Claim 7 including a layer of vitreous fiber.

9. A lining for in situ rehabilitation of a pipe comprising:

a first layer of polyester;

a layer of woven graphite fiber adjacent said first polyester layer;

a second layer of polyester adjacent said woven graphite fiber layer and spaced from said first polyester layer by said woven graphite fiber layer; and

said lining being impregnated with an epoxy resin.

10. The lining of Claim 9 further comprising a layer of synthetic fiber positioned between said first polyester layer and said second polyester layer.

11. A lining for in situ rehabilitation of a pipe line comprising:

a composite having:

a first layer of polyester;

a layer of woven graphite fiber adjacent said first polyester layer;

a second layer of polyester adjacent said woven graphite fiber layer and spaced from said first polyester layer by said woven graphite layer; and

a tubular shaped polyurethane bladder;

said composite formed into a tubular shape surrounding said bladder;

said lining impregnated with an epoxy resin which has been cured by heat generated by electrical resistance caused by inducing an electric current through said woven graphite fiber layer.

12. The lining of Claim 11 wherein said composite further comprises a layer of synthetic fiber positioned between said first polyester layer and said second polyester layer.

13. A method for rehabilitating a pipe comprising the steps of:

providing a tube of lining around a tubular shaped p lyurethane bladder, said lining having an outer layer of polyester, and an inner layer of polyester being positioned adjacent said bladder, and a layer of woven graphite fiber contiguously disposed between said outer polyester layer and said inner polyester layer;

impregnating said lining with a resin;

positioning said lining and said bladder along an interior section of a hollow pipe line having a substantially tubular shaped interior wall;

inflating said bladder so that said lining is forced against said interior wall;

inducing an electrical current through said woven graphite fiber layer sufficient to resistively heat said woven graphite fiber layer to cause said resin impregnated within said lining to cure.

14. The method of Claim 13 further comprising the step of providing a synthetic fiber layer positioned between said inner polyester layer and said outer polyester layer of said lining.

15. The method of Claim 13 wherein said resin is an epoxy.

16. A method for rehabilitating and lining a pipe comprising the steps of:

providing a tube of lining around a tubular shaped inflatable bladder, said lining comprising a conductive layer;

impregnating said lining with a resin;

positioning said lining and said bladder along an interior section of a hollow pipe line having a substantially tubular shaped interior wall;

inflating said bladder so that said lining is forced against said interior wall;

inducing an electrical current through said conductive layer sufficient to resistively heat said conductive layer to cause said resin impregnated within said lining to cure.

17. The method of Claim 16 wherein said conductive layer comprises woven graphite fiber.

18. The method of Claim 16 wherein said resin is an epoxy resin.

19. The method of Claim 16 wherein said inflatable bladder is polyurethane.

20. In a method of curing a preformed molded composite comprising fiberglass and woven graphite fiber, the method comprising the steps of:

impregnating said composite with a resin; and forming said composite in a mold, the improvement comprising:

providing an internal conductive element; and

inducing an electric current through said conductive element sufficient to raise the temperature of said conductive element by resistive heating to cure the resin.

21. Th method of Claim 20 wher in said conductive element comprises woven graphite fiber.

22. In a method of curing a preformed molded composite pr formed into a boat hull shape comprising fiberglass, the method comprising the steps of:

impr gnating said composite with a resin and forming said composite in a mold, the improvement comprising the steps of:

providing an internal conductive element; and

inducing an electric current through said conductive heating element sufficient to raise the temperature of said conductive element by resistive heating to cure the resin.

23. The method of Claim 22 wherein said conductive element comprises woven graphite fiber.

24. A method of forming a pipe lining comprising the steps of:

providing a tubular shaped cured epoxy resin impregnated composite having an interior surface and an exterior surface, said composite including an outer layer of polyester, an inner layer of polyester, and a layer of woven graphite fiber contiguously disposed between said outer polyester layer and said inner polyester layer, said outer polyester layer defining said exterior surface and said inner polyester surface defining said interior surface; and

providing a tubular shaped polyurethane bladder positioned within said composite and thermally bonded to said interior surface of said composite.

25. A method of reforming a cured composite element comprising:

providing a composite element impregnated with a thermosetting resin which has been allowed to cure;

heating said composite element sufficiently to cause said resin to achieve an elastic state; and

applying pressure to said composit element sufficient t reform at least a p rtion of said composite element while said resin is in said elastic state.

26. Th method of Claim 25 wherein said resin has a predetermined glass transition temperature and said composite element is heated to about said glass transition temperature.

27. The method of Claim 25 wherein said resin comprises an epoxy.

28. The method of Claim 25 wherein said composite element includes a conductive element and said composite element is heated by inducing an electric current through said conductive element to resistively heat said conductive element.

29. The method of Claim 28 wherein said conductive element comprises a layer of graphite fiber.

30. The method of Claim 25 wherein said method includes maintaining said pressure while said resin recures.

31. The method of Claim 25 wherein said composite element comprises a pipe lining.

32. The method of Claim 25 wherein said composite element is placed in a mold.

33. A method of reforming a cured pipe lining comprising:

providing a pipe lining impregnated with a thermosetting resin which has been allowed to cure;

heating said pipe lining sufficiently to cause said resin to achieve an elastic state; and

applying pressure to said pipe lining sufficient to reform at least a portion of said pipe lining while said resin is in said elastic state.

34. The method of Claim 33 wherein said lining c mprises a conductive el ment.

35. The method of Claim 34 wherein said pipe lining is heated by inducing an electric current through said conductive element to resistively heat said conductive element.

36. The method of Claim 35 wherein said conductive element comprises a layer of graphite fiber.

37. The method of Claim 33 wherein said resin comprises an epoxy.

38. The method of Claim 33 wherein said method includes maintaining said pressure until said resin recures.

39. A method of reforming a cured pipe lining comprising:

providing a pipe lining having a conductive layer, said pipe lining being impregnated with a thermosetting resin which has been allowed to cure;

inducing an electric current through said conductive layer sufficient to resistively heat said conductive layer to cause said resin to achieve an elastic state;

applying pressure to said pipe lining sufficient to reform at least a portion of said pipe lining while said resin is in said elastic state.

40. The method of Claim 39 wherein said method includes positioning an inflatable bladder within said pipe liner to be reformed.

41. The method of Claim 40 wherein said method includes inflating said bladder until it comes into contact with said pipe lining and reforms at least a portion of said pipe lining while said resin is in said elastic stat .

42. The method of Claim 39 further comprising maintaining said pressure until said resin in said elastic state recures.

43. The method of Claim 40 wherein said resin comprises an epoxy.

44. The method of Claim 39 wherein said resin has a predetermined glass transition temperature and said pipe lining is heated to about said glass transition temperature.

45. A method of reforming a cured pipe lining used for in situ rehabilitation of a pipe comprising:

providing a pipe lining to be reformed having a conductive layer positioned inside said pipe, said pipe lining impregnated with a thermosetting epoxy resin system which has been allowed to cure, said epoxy resin system having a predetermined glass transition temperature;

positioning an inflatable tubular shaped bladder within said pipe lining

inducing an electric current through said conductive layer sufficient to resistively heat said pipe lining to about said glass transition temperature of said cured epoxy resin system and thereby causing said cured epoxy resin system to achieve an elastic state;

inflating said bladder sufficiently to engage and reform at least a portion of said pipe lining while said resin is in said elastic state; and

allowing said pipe lining to cool.

46. The method of Claim 45 wherein said conductive element is a layer of graphite fiber.

47. Th method of Claim 45 wherein said bladder is maintained in a inflated state while said pipe lining is allowed to cool.

48. The pipe lining of Claim 45 wherein said bladder thermally bonds to and becomes part of the pipe lining which is being reformed.

FIG. 1

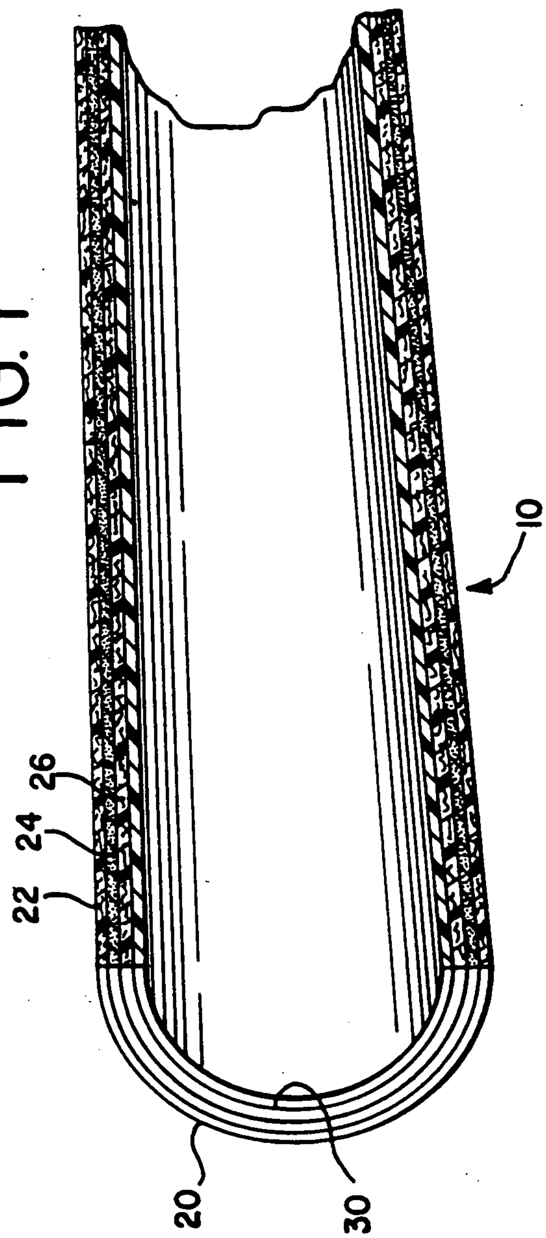
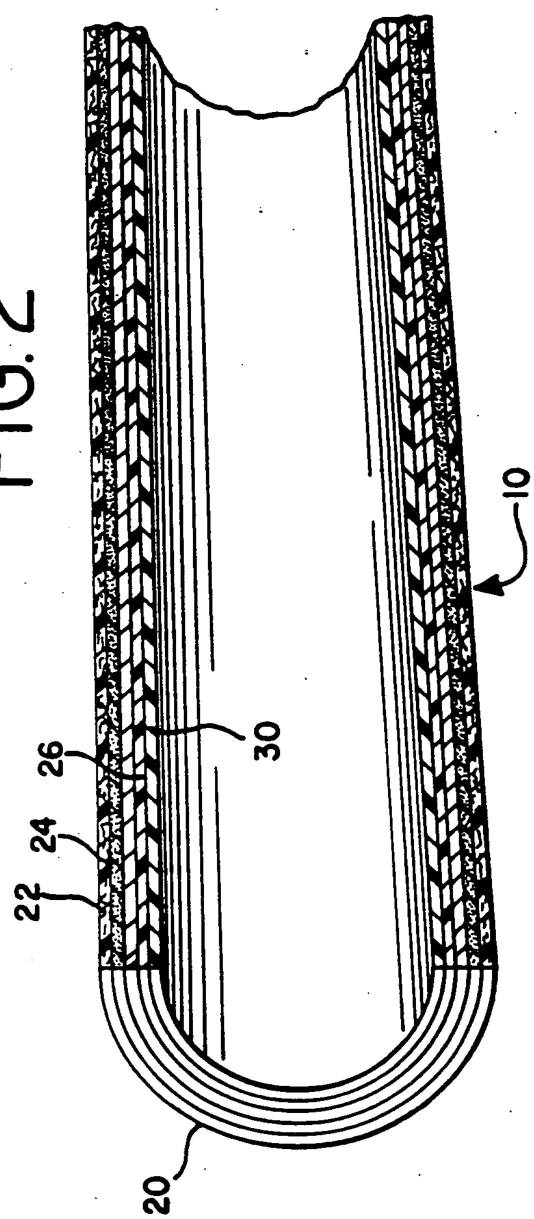


FIG. 2



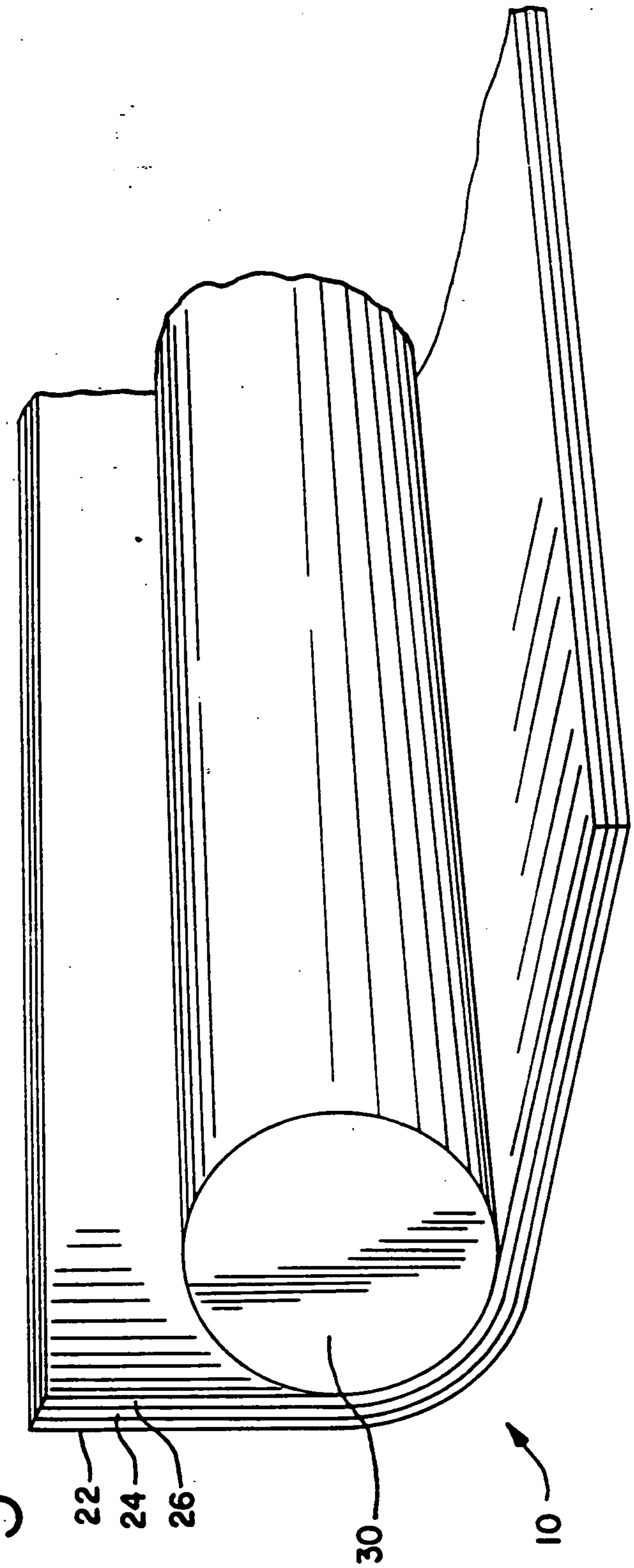


FIG. 3

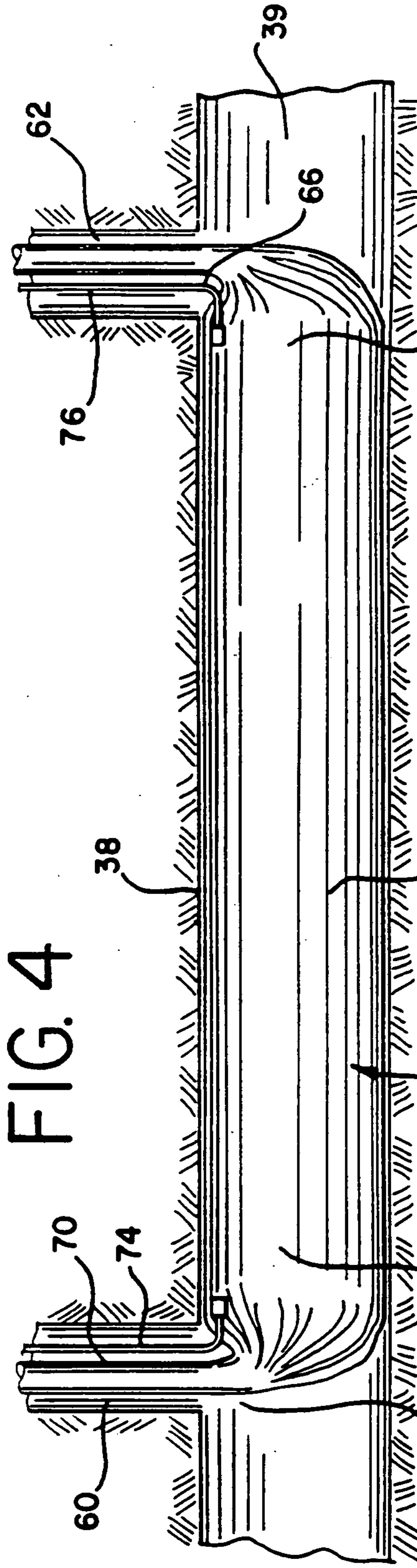


FIG. 4

FIG. 5

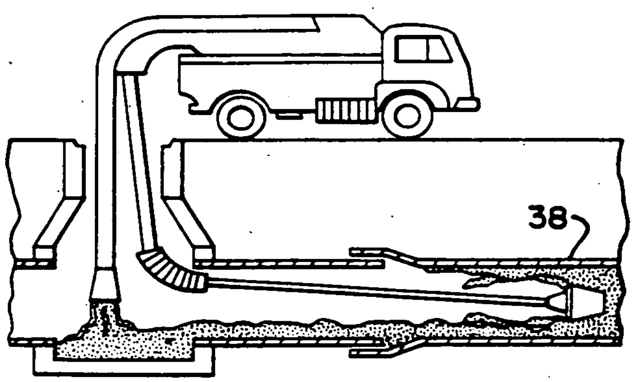


FIG. 6

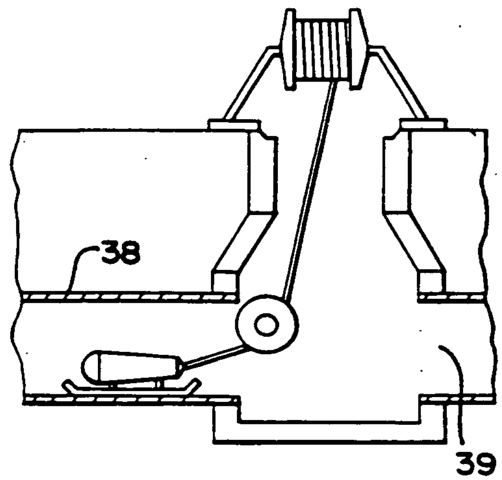


FIG. 7

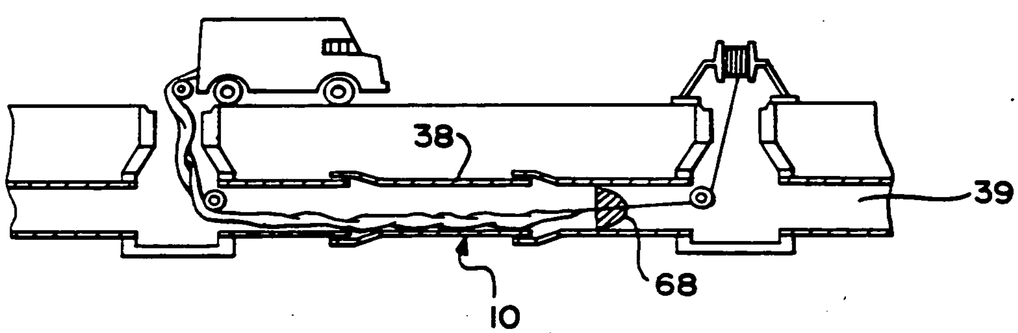
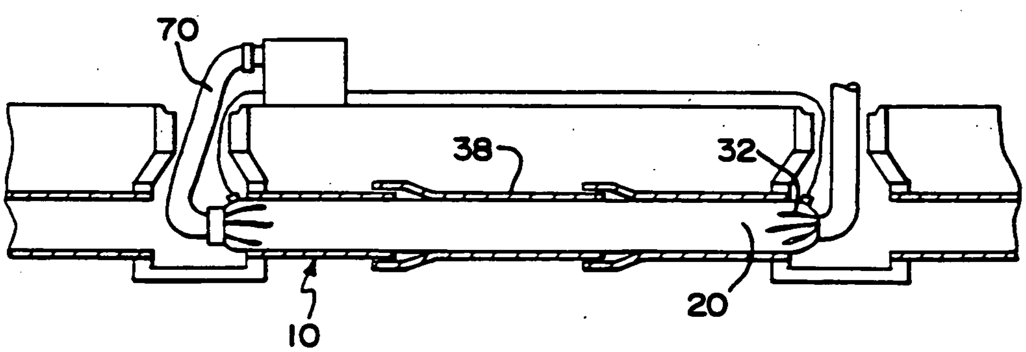


FIG. 8



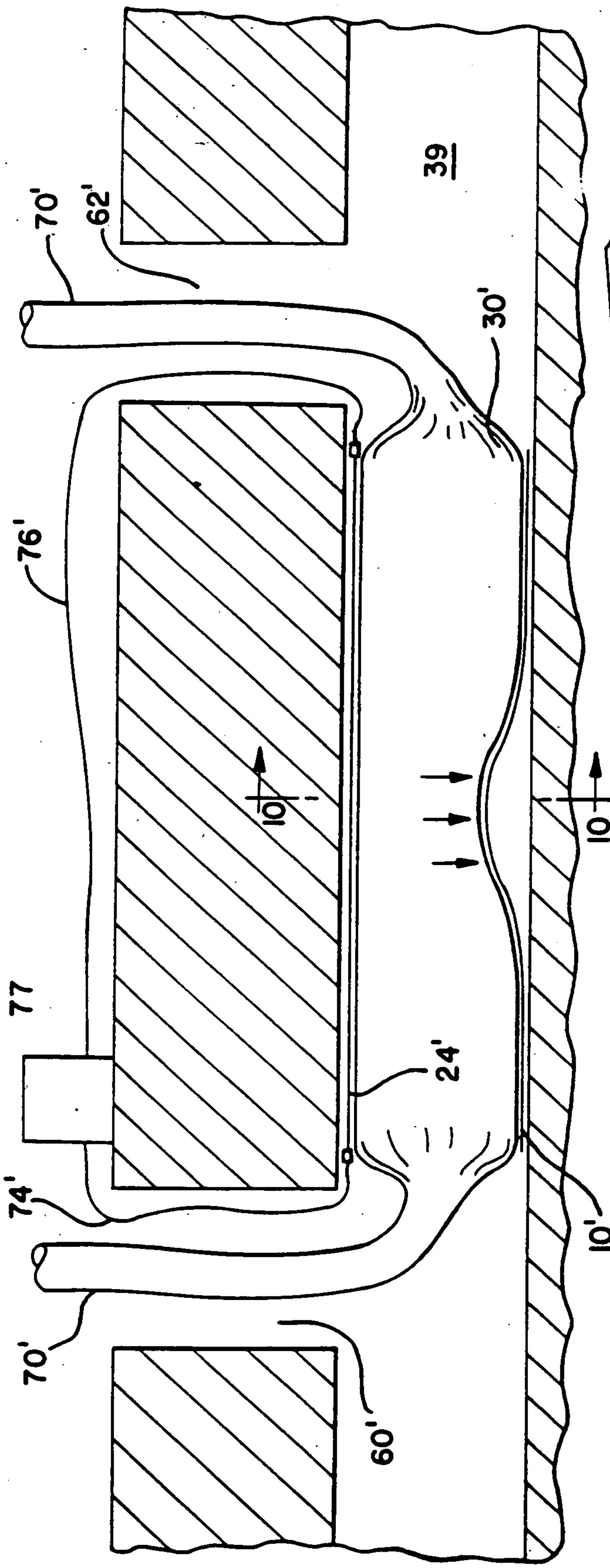


FIG.9

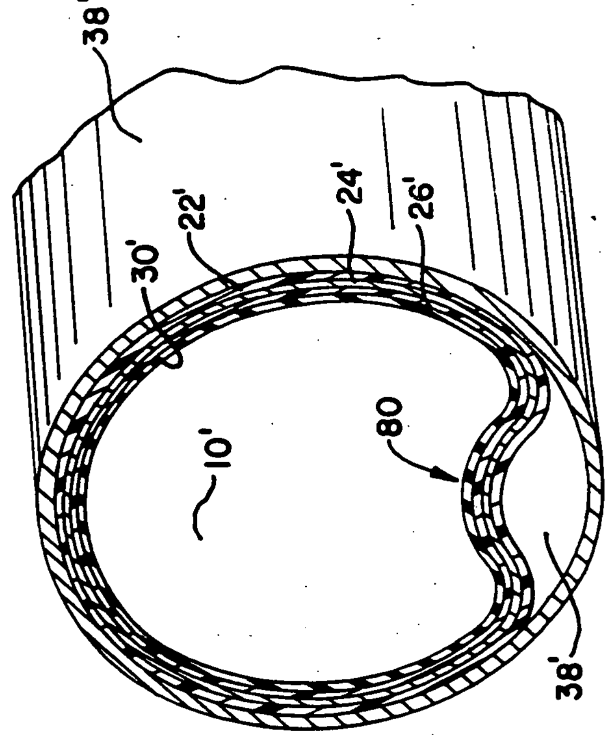


FIG.10

INTERNATIONAL SEARCH REPORT

International Application No PCT/US 92/07751

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 F16L55/165

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	F16L

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category °	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No.[13]
X	FR,A,2 542 416 (VERNHES) 14 September 1984	1,2,5,7, 8,16,25, 28,30, 31, 33-35, 38-42,45
	see page 2, line 3 - line 31; claims 1-20; figures 1-5	
A		3,4,6, 9-15, 17-24, 27,29, 36,37, 43,44, 46-48

	-/--	

° Special categories of cited documents : [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

5 **IV. CERTIFICATION**

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
05 JANUARY 1993	25. 01. 93
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT FFICE	ANGIUS P.

International Application No PCT/US 92/07751

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	US,A,4 768 562 (STRAND) 6 September 1988 see column 2, line 25 - line 44 ---	1,7,9, 11,13, 16,28, 33-35, 39,45
A	US,A,4 600 615 (HYODO ET AL.) 15 July 1986 see column 2, line 34 - line 51 ---	1,6,9, 15,18, 33,37, 39,43
A	EP,A,0 351 570 (MUELLER ET AL.) 24 January 1990 see claims 1-7 -----	1,5-16, 18, 24-27, 33,37, 40-45,47

Form PCT/ISA/210 (extra sheet) (January 1985)

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. US 9207751 SA 65187

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information. 05/01/93

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
FR-A-2542416	14-09-84	None		
US-A-4768562	06-09-88	US-A-	4972880	27-11-90
US-A-4600615	15-07-86	GB-A-	2171484	28-08-86
		GB-A,B	2208823	19-04-89
		US-A-	4871413	03-10-89
EP-A-0351570	24-01-90	DE-A,C	3906057	25-01-90
		DE-U-	8809305	23-11-89
		AU-B-	612858	18-07-91
		AU-A-	3719789	25-01-90
		DE-A-	3937478	16-05-91
		EP-A-	0393304	24-10-90
		JP-A-	2248797	04-10-90
		US-A-	5029615	09-07-91

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82